

MULTI-CHIP STACKED DEVICES

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FIELD OF THE INVENTION

This invention relates to a multiple die module that has a thickness the same or less than a standard package but has two or more stacked die, thereby increasing device density.

BACKGROUND OF THE INVENTION 10

Semiconductor devices are typically constructed en masse on a silicon or gallium arsenide wafer through a process which comprises a number of deposition, masking, diffusion, etching, and implanting steps. When the devices are sawed into individual rectangular units, each takes the form of an integrated circuit (IC) die. In order to interface a die with other circuitry, it is (using contemporary conventional packaging technology) mounted on a lead frame paddle of a lead-frame strip which consists of a series of interconnected lead frames, typically ten in a row. The die-mounting paddle of a standard lead frame is larger than the die itself, and it is surrounded by multiple lead fingers of individual leads. The bonding pads of the die are then connected one by one in a wire-bonding operation to the lead frame's lead finger pads with extremely fine gold or aluminum wire. Following the application of a protective layer to the face of the die, it, and a portion of the lead frame to which it is attached, is encapsulated in a plastic material, as are all other die/lead-frame assemblies on the lead-frame strip. A trim-and-form operation then separates the resultant interconnected packages and bends the leads of each package into the proper configuration.

In the interest of higher performance equipment and lower cost, increased miniaturization of components 35 and greater packaging density have long been the goals of the computer industry. IC package density is primarily limited by the area available for die mounting and the height of the package. Typical computer-chip heights in the art are about 0.110 inches. A method of 40 increasing density is to stack die or chips vertically.

U.S. Pat. No. 5,012,323, issued Apr. 30, 1991, having a common assignee with the present application, discloses a pair of rectangular integrated-circuit dice mounted on opposite sides of the lead frame. An upper, 45 smaller die is back-bonded to the upper surface of the lead fingers of the lead frame via a first adhesively coated, insulated film layer. The lower, slightly larger die is face-bonded to the lower surface of the lead extensions within the lower lead-frame die-bonding region 50 via a second, adhesively coated, insulative, film layer. The wire-bonding pads on both upper die and lower die are interconnected with the ends of their associated lead extensions with gold or aluminum wires. The lower die needs to be slightly larger in order that the die pads are 55 accessible from above so that gold wire connections can be made to the lead extensions (fingers).

U.S. Pat. No. 4,996,587 (referred to hereafter as '587) shows a semiconductor chip package which uses a chip carrier to support the chips within a cavity. The chip 60 carrier as shown in the figures has a slot that permits connection by wires to bonding pads which, in turn, connect to the card connector by conductors. An encapsulation material is placed only on the top surface of the chip in order to provide heat dissipation from the 65 bottom surface when carriers are stacked.

A Japanese Patent No. 56-62351(A) issued to Sano in 1981 discloses three methods of mounting two chips on

a lead frame and attaching the pair of semiconductor chips (pellets) to a common lead frame consisting of:
 method 1 two chips mounted on two paddles;
 method 2 one chip mounted over a paddle and one
 5 below not attached to the paddle; and
 method 3 one chip attached above and one chip attached below a common paddle.

The chips are apparently wired in parallel as stated in the "PURPOSE" of Sano.

10 The chips of patent '587 are also apparently wired in parallel by contacts on the "S" chips which contact the connection means.

It is the purpose of this invention to provide multiple stacked dies assembled in a special vertical configuration such that as many as four encapsulated dies will have a height no greater than existing 0.110-inch high dies and also have a separate lead and lead finger for each die pad connection.

20 SUMMARY OF THE INVENTION

The invention generally stated is a multiple-die low-profile semiconductor device comprising:
 a lead-frame paddle supported by a lead frame;

25 a controlled, first, thin-adhesive layer affixing a first die above the paddle;

a plurality of thin wires having a first low-loop wire bond to a plurality of first die-bonding pads and a second wire bond to a plurality of adjacent lead-frame lead fingers;

30 a second thin-adhesive layer affixing a second die above the first die;

a second plurality of thin wires having low-loop wire bonds to a plurality of second die-bonding pads and

35 second wire bonds to the plurality of lead fingers; additional dies affixed above the second die, by additional subsequent layers of adhesive and having additional thin wires bonded to addition bonding pads and lead fingers; and

40 an encapsulated layer surrounding all dies, adhesive layers, and thin wires.

Other objects, advantages, and capabilities of the present invention will become more apparent as the description proceeds.

45 BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be better understood and further advantages and uses thereof may become more readily apparent when considered in view of the following 50 detailed description of exemplary embodiments, taken with the accompanied drawings, in which:

FIG. 1 is a partial plan view of the stacked die, lead fingers, and bonded wires of the present invention; and

55 FIG. 2 is a side elevation taken through lines 2—2 of FIG. 1 showing a four die stacking.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

60 Referring to FIG. 1, the stacked die device 10 is shown prior to encapsulation disclosing the top die 12 mounted the paddle 14 and other dies 16, 18, and 20 (FIG. 2) which are adhesively connected to each other by a controlled-thickness thermoplastic-adhesive layer 65 at 22. Thermoplastic indicating the adhesive sets at an elevated temperature. The group of four dies are attached to the paddle 14 by a controlled thin-adhesive layer 24.

Each of the die bonding pads 26 in double rows are electrically connected to multiple lead fingers 28A, 28B, 28C . . . 28N by thin (0.001 inch) gold or aluminum wires 30A, 30B, 30C . . . 30N; gold being the preferred metal. For clarity, only part of the 18 bonding pads, 5 wires, and fingers are shown. The critical bonding method used at the die end pad 26 is an ultrasonic ball bond as named by the shape of the bond as at 32. This first-installed bond and formed gold wire are low-loop wire bonds as seen at critical dimension 34, as will be 10 described later.

The other end of gold wires 30 are attached to the lead fingers by a wedge bond 36, which is also an ultrasonic bond, indicating the use of ultrasonic energy to heat the wire 30 as it is compressed against the lead 15 finger 28. The wedge bond is not used on the die because the bonding machine contacts the bonding surface and could damage this critical surface. The lead fingers may be formed upward as at 38 to permit the use 20 of shorter wires 30.

Paddle 14 which supports the stack is attached to the lead frame typically at four corners as at 40 and also typically, in this application, would have a downset from the lead frame and lead fingers 28 as at dimension 42. The stack is finally encapsulated by a plastic or 25 ceramic at 44.

A dimensional analysis is provided by referring to FIG. 2.

By careful control of layer thicknesses, it is possible to fabricate a four-stack die device having an overall 30 height 46 of about 0.110 inches which is the same height as a current single die. Starting at the bottom, the encapsulation thickness 48 is between 0.010 and 0.012 inches. The paddle 74 thickness 50 can be between 0.005 and 0.010 inches and is a matter of choice. The controlled 35 adhesive-layer thickness 52 can be from 0.001 to 0.005 inches. The individual dies 20, 18, 16, and 12 each have a thickness 54 of 0.012 inches and the critical controlled, adhesive-layer thicknesses 56 between each die are between 0.008 and 0.010 inches. These thin layers have to 40 be slightly greater than the low-loop wire dimension 34, which is about 0.006 inches. Finally, the top encapsulation thickness 58 is between 0.010 and 0.012 inches so as to cover the top loop.

Thus, it can be seen by carefully controlling and 45 minimizing the adhesive layer thicknesses 56, the top and bottom encapsulation thicknesses 48 and 58, and the paddle adhesive layer 52 that it is possible to have an overall height between 0.108 and 0.110 inches overall for the four-stack die.

If the looser tolerances were used for a two-stack die, the height at 60 would be between 0.058 and 0.073 inches and for a three-die stack it would be from 0.078 to 0.100 inches.

The fabrication of these two or four-stack die devices, necessarily, has to be from the bottom up, since it is not possible to form the die pad wire ball bond 32 on the lower dies 16, 18, and 30, if the four dies are already stacked. This is due to the overhead space required by 60 the wire bond machine.

The die pads 26 of each die can be each connected to an individual lead finger 28 or the dies can be wired in parallel. The former configuration would, therefore,